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Controlling chaos caused by the current-driven ion acoustic instability in a laboratory plasma using delayed feedback

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Controlling chaos caused by the current-driven ion acoustic instability is attempted using the delayed continuous feedback method, i.e., the time-delay auto synchronization (TDAS) method introduced by Pyragas [Phys. Lett. A 170 (1992) 421.] with flexibility.

1. Introduction

Over the past decade, the problem of controlling chaos has attracted great interest in many fields, such as lasers,[1] motivated by the importance of the role. The serious role of turbulence in fusion-oriented plasmas creates a special interest in controlling chaos.

An effective method of controlling chaos, which has been proposed by Ott, Grebogi, and Yorke (OGY),[2] has attracted much attention. On the other hand, Pyragas[3] has proposed a time-delay feedback technique, i.e., the time-delay auto synchronization (TDAS) method,[4] which is appropriate for the experimental systems working in real time.

We have attempted chaos control using the TDAS method based on the Pyragas technique in order to attain stable chaos control.

2. Experimental set up

The experiments are performed using a Double Plasma device. Argon gas is introduced into the chamber at a pressure of 4.0×10^{-4} Torr. Typical plasma parameters are as follows: the electron density $n_e \sim 10^8$ cm^{-3}, electron temperature $T_e \sim 0.5$-1.0 eV.

The current-driven ion acoustic instability is excited by the two parallel mesh grids installed into the chamber (G_1 and G_2). A dc potential V_m is applied to G_1 in order to excite the current-driven ion acoustic instability, and G_2 is kept at floating potential. Time series signals for analysis are obtained from the fluctuating components of the currents on the V_m biased mesh grids.

The experiments in controlling chaos are performed by applying the feedback signal $F(x)$ to the floating mesh grid G_2. The feedback signal $F(x)$ is generated from $x(t)$, using the electronic circuit based on the TDAS method.

Chart of experimental setting is shown in Fig. 1.

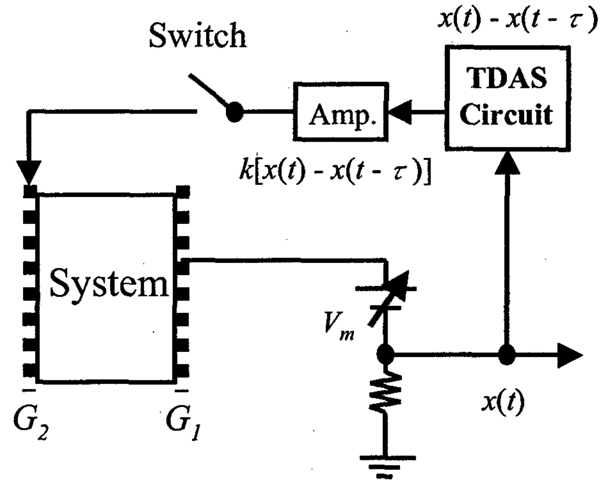

Figure1: Chart of experimental setting.

3. Experimental results and discussions

When the grid bias V_m exceeds a threshold, the current-driven ion acoustic instability is excited. When V_m exceeds 40 V, a limit cycle oscillation appears. Then, according to increasing V_m, the system becomes chaotic via bifurcation. The system presents a typical chaotic feature around V_m = 54 V. The TDAS control

is applied to the typical chaotic state.

Figure 2 shows the stabilization process of chaos using the TDAS method. Figure 2(a) and (b) correspond to the time series signal and the feedback signal during the transition from the uncontrolled to the controlled state, respectively. Here, τ and k are 20 μs (~ 1.16 period) and 0.28, respectively. The details of the state before and after switching on the control is depicted in Fig. 3, showing the time series signal, and $I(t)$ – $I'(t)$ trajectories in the phase plane, the power spectra, respectively. It is found that the system changes from chaotic to periodic, maintaining the instability, and the fundamental mode (~ 70 kHz) of the unstable periodic orbit is selected during controlling process.[5]

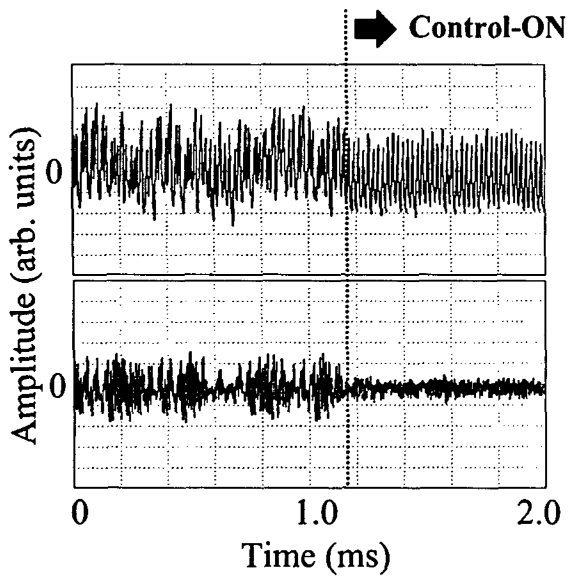

Figure2: The stabilization process of chaos using the TDAS method.

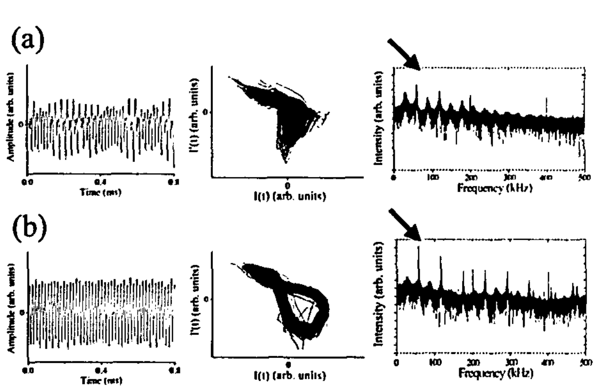

Figure3: The details of the state before and after switching on the control.
(a) Before control, (b) after control.

4. Further issue

Delayed feedback is applied to the periodic oscillation (V_m = 40 V), and the dynamical behavior is studied.

When the TDAS method is applied to periodic nonlinear regime and arbitrary delay time τ is chosen, the periodic state changes to various states such as "Type-1 intermittency" and unstable "period-3" orbits in period-doubling bifurcation, as shown in Fig. 4.

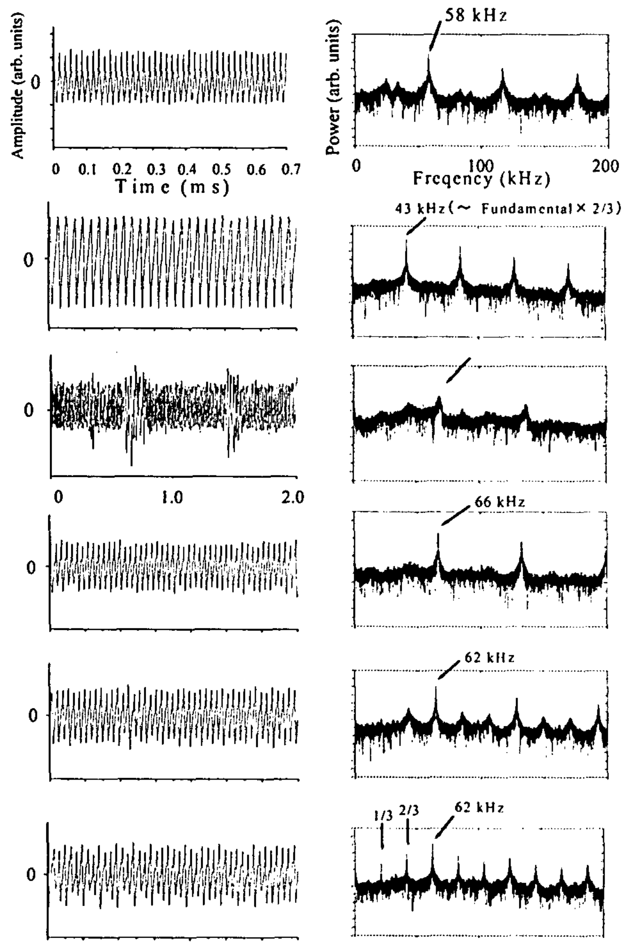

Figure4: Dynamical behavior of the system as a function of τ.

5. References

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